San Francisco longshoremen who underwent multiphasic screening in 1951 were studied for factors that predisposed to fatal coronary heart disease and stroke in an 18-year follow-up. Men with more sedentary jobs had higher death rates from coronary disease, but similar death rates from stroke than cargo handlers. These diverse findings were interpreted to signify that physical activity influences myocardial function more than the atherosclerotic process. Other factors increasing coronary mortality were pre-existing heart disease, higher blood pressure, cigarette indulgence, and heavier weight-for-height. Factors increasing stroke mortality were diagnosed heart disease, higher blood pressure, and abnormal glucose metabolism.

CHARACTERISTICS OF LONGSHOREMEN RELATED TO FATAL CORONARY HEART DISEASE AND STROKE

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In an 18-year follow-up of 3,263 longshoremen who had undergone multiphasic screening examinations in 1951, we studied six characteristics for their influence on risk of death from coronary heart disease and stroke. Results of an earlier study[1] were extended and amplified by attention to additional characteristics of high risk. Among the characteristics we found to be associated with increased death rates from coronary heart disease or stroke were reduced physical activity of work, indulgence in cigarette smoking, higher blood-pressure level, increased weight-for-height, diagnosed heart disease, and abnormal glucose metabolism. Work activity attracted special attention because of the high energy expenditure demanded by some longshoring jobs.

Methods

Cut-points were chosen for these characteristics, determined for men aged 35–64 years at the initial screening examination, in order to divide the total population of subjects into groups presumed to be at higher and lower risk. Cargo handlers, shown to represent the more physically active longshoremen,[2] comprised 68 per cent of the study population, the remaining one-third being regarded as less active. Cigarette-smoking of one or more packs per day identified 39 per cent of the longshoremen; systolic blood pressure above mean level, 44 per cent; weight-for-height above mean, 50 per cent; diagnosed heart disease (causes 410–443, International Classification of Diseases, seventh revi-

sion), 7 per cent; and abnormal glucose metabolism (diagnosed diabetes mellitus or a blood-sugar level of 205 mg per cent or more one hour after a 50 gm sucrose load),[3] 5 per cent. Details of methods of group determination have been described earlier.[1]

Longshoremen expend more energy in the conduct of their jobs than workers in most other industries. We have estimated energy and oxygen costs of cargo-handling and of less active longshoring tasks in 1951, using energy requirements on holdmen handling a variety of cargo[2] and similar data from other work forces.[4,5] Weighting the results for the proportional contribution of specific job classifications, some more rigorous than others, we find cargo handlers to use 6.7 calories per minute (1.34 liters of oxygen), and less active longshoremen, 2.8 calories per minute (0.56 liters of oxygen) during comparable work periods. Considering both work and rest periods, the difference in energy expenditure between cargo handlers and others less active converts into about 925 calorise during an eight-hour work day.

We identified decedents from records of the International Longshoremen's and Warehousemen's Union–Pacific Maritime Association Welfare Fund, and we traced the starting population by death clearance procedures,[6] losing less than one per cent to 18-year follow-up observations. Official death certificates identified coronary heart disease and stroke deaths occurring between the initial screening examination of 1951 and 1969.

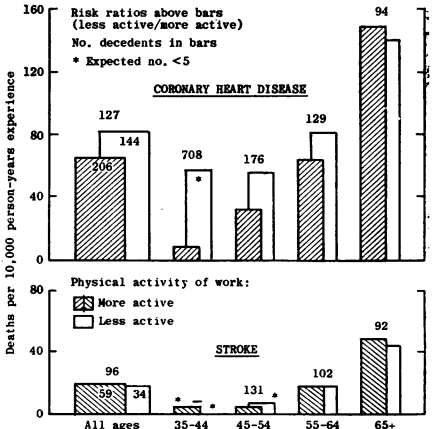
For subjects separated into presumed high- and low-risk groups, we compiled person-years experience by single years of age and combined the results into 10-year age classes to steady the numbers. The groups were then compared in terms of cause-specific rates representing deaths per 10,000 person-years experience. Rates are represented as age-specific or age-adjusted (direct method by 10-year age classes) figures. Differences in rates between high- and low-risk groups are given as: (a) risk-ratios, which compare death rates in the presence versus the absence of a characteristic (multiplied by 100), and (b) relative death ratios, which show the effect of two or more characteristics present in combination as compared with death rates in their absence.

The conventional formula for computing standard errors was modified by adjusting to person-years experience, rather than the population-at-risk, in significance testing.

Results

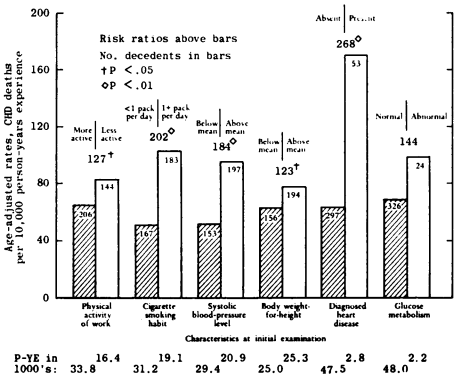
Of the 3,263 longshoremen aged 35–64 years at time of examination in 1951, a total of 1,098 were known to be dead by the 1969 follow-up. Among them were 350 who died from an underlying cause of coronary heart disease (cause 420, I.C.D.) and 93 who died from stroke

Figure 1—Death rates from coronary heart disease and stroke among San Francisco longshoremen in an 18-year follow-up study, by physical activity of work at initial examination (1951) and age at death.



Risk-ratios represent rates for less active longshoremen divided by rates for cargo handlers (×100).

Figure 2—Age-adjusted death rates from coronary heart disease (CHD) among San Francisco longshoremen in an 18-year follow-up study, by six characteristics assessed in 1951.



Risk-ratios represent rates for longshoremen with higher risk divided by rates for those with lower risk (×100).

(46 of underlying cause 330 or 331, and 47 of cause 332 or 334). These totals represent death rates of 69.7 and 18.5 respectively per 10,000 person-years experience in the 18-year period. The mean (±S.D.) age at death was 62 (±9) for coronary disease and 64 (±8) for stroke, while survivors ranged in age from 53–82 years.

Work Activity

Figure 1 shows age-adjusted and age-specific death rates among San Francisco longshoremen during the 18-year follow-up period in terms of deaths per 10,000 person-years experience, by level of physical activity and age at death. The figure also presents death risk-ratios (×100), which are obtained by dividing rates for less active longshoremen by rates for cargo handlers. The upper panel of the chart refers to coronary heart disease and the lower panel to stroke.

For coronary heart disease, the death rate is noticeably lower for actives than for inactives in the total and at younger ages, but the difference disappears in the upper age bracket. The risk-ratios, 127 for the total, decline from 708 at 35–44 years, to 176 at 45–54, 129 at 55–64, and 94 at 65 years and over. In contrast, physical activity or inactivity does not affect risk of fatal stroke, either for the total or at any of the age classes available for study.

The decreasing risk-ratio with age, seen here for coronary disease, may represent an earlier death with a reduction of the least active workers in the population-at-risk before age 65 years. Other explanations of the decrease with age may include: (a) the most highly susceptible group of physically less active workers were winnowed out through coronary death from other characteristics; and (b) older longshoremen changed their work habits, during the follow-up period, from physically tasking to more sedentary jobs or to retirement status.

Characteristics of High Risk

Figure 2 gives age-adjusted death rates from coronary heart disease in the 18-year follow-up for each of six characteristics of high risk assessed at the initial examination. Age-specific rates are not given since, with the exception of work activity (already discussed), there was no trend with age for the remaining five characteristics. The figure also gives risk-ratios computed by dividing rates in the presence of these high-risk characteristics by rates in their absence (×100).

As already shown, less active longshoremen sustained a death rate 27 per cent higher than cargo handlers. Smoking one or more packs of cigarettes per day doubled the risk of coronary death over that for smoking less or not at all. Risk among men with systolic blood pressure above mean levels exceeded that among those with lower levels by 84 per cent. An excess death rate of 23 per cent accompanied longshoremen with body weight above mean levels as com-

pared with the rate for those less hefty. Men with diagnosed heart disease sustained a coronary death rate 168 per cent higher than that for peers without such diagnosis. (Although not shown in the figure, the corresponding excess for men with diagnosed coronary heart disease was 267 per cent.) And last, although not statistically significant, an excess death rate of 44 per cent attended men with abnormal glucose metabolism over that for those with normal glucose metabolism.

These first-order relationships between six characteristics of high risk and coronary mortality suggest a rank order by declining strength of: diagnosed heart disease, cigarette smoking, higher blood-pressure level, less strenuous work activity, heavier weight-for-height, and abnormal glucose metabolism. Although a history of heart disease carries a higher risk-ratio for coronary death, it has less public health significance than either cigarette habit or higher blood-pressure level because of its lower prevalence.

Figure 3 displays age-adjusted death rates from stroke in the 18-year follow-up together with corresponding risk-ratios on the two-level scales, for each of the same six characteristics. Three of the six associated with death rates from stroke. Longshoremen with systolic blood pressure above mean levels sustained a stroke death rate 253 per cent higher than that for men with lower levels. Risk among men with diagnosed heart disease exceeded that among those without such diagnosis by 529 per cent. (Again not shown, the corresponding excess for men with diagnosed coronary heart disease was 174 per cent.) And finally, an excess death rate of 166 per cent accompanied longshoremen with abnormal glucose metabolism as compared with the rate for those with normal findings. Rank-order listing from strongest to weakest correlate is: diagnosed heart disease, systolic blood-pressure level, and glucose metabolism.

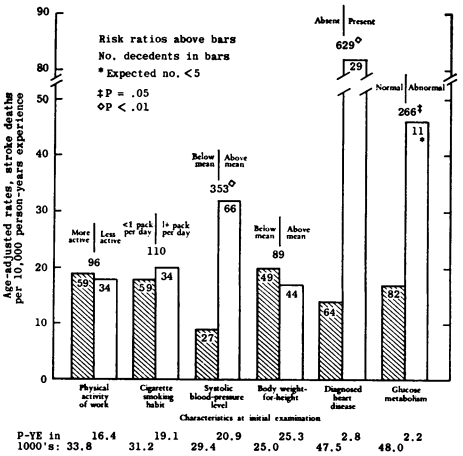
Work Activity and Other Characteristics

Figure 4 gives age-adjusted death rates from coronary heart disease in the 18-year follow-up for combinations of work activity and each of the five other characteristics on the two-level scales studied. The figure also gives risk-ratios obtained by dividing rates for less active longshoremen by rates for cargo handlers at each level of the other characteristics. In general, for both low- and high-risk levels of the other characteristics, cargo handlers tended to experience lower death rates than their more sedentary mates. The differences are significant, however, only for men of heavier weight-for-height and diagnosed heart disease, where the excess risks are 58 and 170 per cent, respectively.

Unspecified Combinations of Characteristics

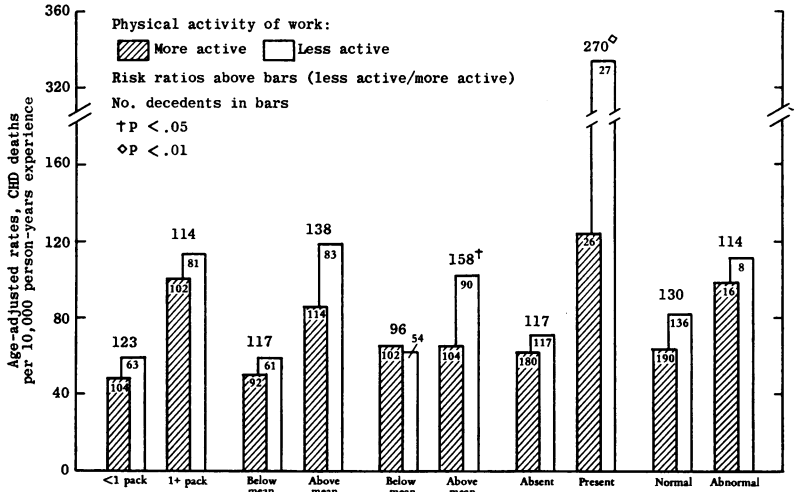
Figure 5 explores death rates from coronary heart disease and stroke, to-

Figure 3—Age-adjusted death rates from stroke among San Francisco longshoremen in an 18-year follow-up study, by six characteristics assessed in 1951.



Risk-ratios represent rates for longshoremen with suspected high-risk characteristics divided by rates for those without characteristics (×100).

Figure 4—Age-adjusted death rates from coronary heart disease (CHD) among San Francisco longshoremen in an 18-year follow-up study, by combinations of physical activity of work with each of five other characteristics assessed in 1951.



PY-E in 1000's:	<1 pack	1+ pack	Below mean	Above mean	Below mean	Above mean	Absent	Present	Normal	Abnormal
(more active)	21.8	12.1	19.6	14.2	16.9	16.9	32.0	1.8	32.3	1.5
(less active)	9.4	7.0	9.8	6.7	8.1	8.4	15.5	0.9	15.7	0.7

Risk-ratios represent rates for less active longshoremen divided by rates for cargo handlers (×100).

gether with relative death ratios, for unspecified combinations of any two to five of the six characteristics assessed at the initial examination. Data for absence and single occurrence are also given. None of the study subjects had all six characteristics present at the initial examination. The mean (±S.D.) number of characteristics present was 2.3 (±1.1) for longshoremen who later died from coronary heart disease, 2.3 (±1.1) for those who died from stroke, and 1.7 (±1.0) for survivors to 1969. The upper panel of the figure pertains to coronary heart disease and the lower panel to stroke.

Age-adjusted coronary deaths per 10,000 person-years experience increased steadily from 34 for men with none of the characteristics present to 41 for men with any one, 73 with any two, 105 with any three, and 194 with any four or five. The relative mortality ratios, which increase from 100 to 573 as characteristics are added, restate the same trend. This steady progression, which exceeds a fivefold increase, suggests that effects from these combinations of characteristics on coronary mortality are more than cumulative, that is, potentiating.

Corresponding death rates from stroke were five for longshoremen with none of the characteristics, 11 for those with any one, 18 with two, 30 with three, and 50 with any four or five. Or, in other terms, the relative mortality ratios increase from 100 to 975. This steady progression in stroke mortality may reflect merely a numerical artifact, since only three of the characteristics were associated with stroke. Or, it may represent the release of a suppressive effect imposed by the presence of other characteristics.

Paired Combinations of Characteristics

Figure 6 surveys age-adjusted death rates and relative death ratios for coronary heart disease, by all paired com-

binations of the six characteristics. Again, diagnosed heart disease, cigarette-smoking of one or more packs per day, and higher systolic blood-pressure levels evoked the strongest effects, both when paired together or with any of the other three characteristics. The latter three were about equal in influence.

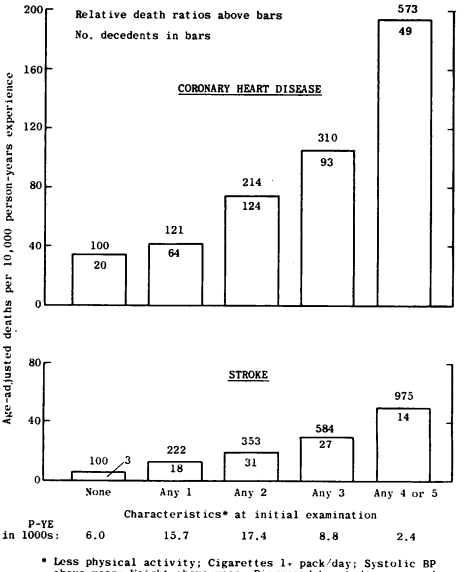
On closer inspection, the paired combination of diagnosed heart disease with less physical activity evoked a synergistic effect on coronary mortality. Systolic blood pressure above mean levels combined with (a) diagnosed heart disease or (b) abnormal glucose metabolism had overlapping influences. Most other characteristics in paired combinations educed an effect greater than expected from the sum of their independent effects.

Figure 7 depicts age-adjusted death rates and relative death ratios for stroke by paired combinations of three characteristics of high risk: systolic blood pressure above mean level, diagnosed heart disease, and abnormal glucose metabolism. Although the experience is limited, pre-existing heart disease paired with either higher blood-pressure level or glucose intolerance, seemed to potentiate longshoremen's risks of stroke mortality. The remaining pair were about additive in effect.

Discussion

In a wide variety of industries[7-9] and in diverse urban jobs,[10-12] physically active men sustain lower death rates from coronary heart disease than their less active fellows. Observations on work activity add similar findings for the longshoring industry, where some jobs demand high energy output. Cargo handlers, who expend 925 calories per work-day more than other longshoremen, sustained a coronary death rate 20 per cent lower than their less active work companions (65 as opposed to 82 per 10,000 person-years experience in an 18-year follow-up). This differential tended to persist when five other characteristics were taken into account (that is, cigarette-smoking habit, systolic blood-pressure level, body weight-for-height, diagnosed heart disease and glucose metabolism). The differential between actives and inactives presumably represents a minimal estimate, since jobs were classified at the initial examination, and job changes during the 18-year follow-up were largely from cargo handling to less active status. Although the prevalence of all characteristics changed over the period studied, the shift in work activity was judged greater than that for most of the other five.[1] Allowance for these considerations would increase further the influence of sedentary work activity on risk of coronary mortality,

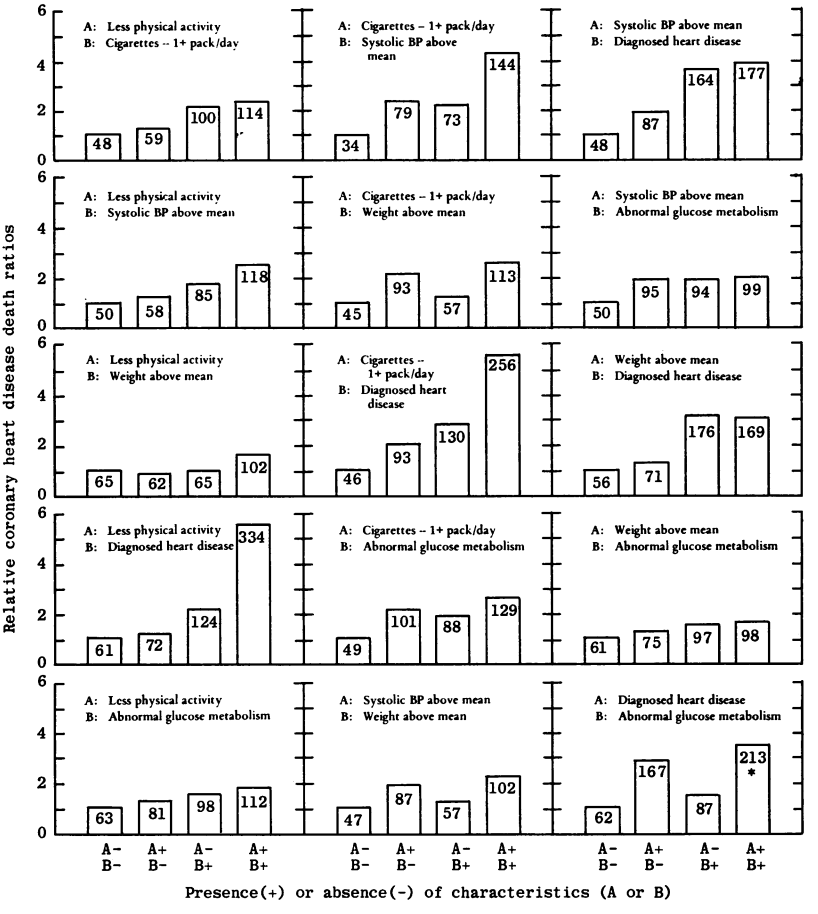
Figure 5—Age-adjusted death rates from coronary heart disease and stroke among San Francisco longshoremen in an 18-year follow-up study, by unspecified combinations of six characteristics assessed in 1951.



* Less physical activity; Cigarettes 1+ pack/day; Systolic BP above mean; Weight above mean; Diagnosed heart disease; and Abnormal glucose metabolism

Relative death ratios represent rates for longshoremen with various combinations of characteristics divided by rates for those without these characteristics (×100).

Figure 6—Relative death ratios for coronary heart disease (CHD) among San Francisco longshoremen in an 18-year follow-up study, by paired combinations of six characteristics assessed in 1951.



Numbers in bars: age-adjusted CHD death rates per 10,000 person-years experience

* Expected no. <5

Age-adjusted coronary death rates for longshoremen without either characteristic represent the baseline for comparison with rates for longshoremen with various combinations of the pair.

relative to the risk imposed by the other characteristics.

Assignment to the strenuous activity of cargo handling was routine on entering the ranks of longshoremen, and such duty was continued for a minimum of five years. Those who shifted to more sedentary tasks had served an average of about 13 years as cargo handlers.[13] An observed 2.4-pound excess of weight (adjusted for age and height) among less active workers as compared with cargo handlers may be presumed due to the reduction in energy expenditure after shift in job assignment rather than to a selective influence present at time of job change. Furthermore, as seen in Figure 4 of the present report, the "sparing effect" of physical activity on coronary mortality occurred among the fat rather than among the lean.

Figure 4 also suggests a salutory ef-

fect of physical exercise among individuals with evidence of diagnosed heart disease. The increased coronary mortality ratio of 170 per cent among inactive as compared with active subjects implies that recommendations of reduced activity are ill-advised in programs of secondary prevention. In fact, the obvious corollary would call for continued or even increased energy expenditure by patients with coronary heart disease.

The other four characteristics—cigarette indulgence, higher blood-pressure level, overweight status, and glucose intolerance—are well-recognized precursors of coronary mortality. Review of their effects in combination, demonstrated here, helps rank them by relative strength and also to assess any cumulative influence.

Cargo handlers and less active longshoremen experienced similar rates of death from stroke (19 and 18 per 10,000 person-years experience in the 18-year period). Considering that work activity shows a "protective effect" on coronary but not on stroke mortality, vigorous energy expenditure seems to exert a delaying influence on disease of the myocardium or its conduction mechanism rather than on atherosclerosis.

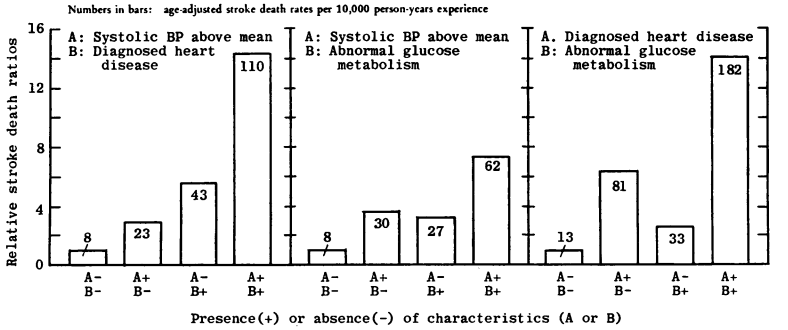
Pre-existing heart disease, higher levels of blood pressure and abnormal glucose metabolism are well established precursors of stroke.[12,14] Present findings help to rank them by strength and combined effects.

Summary

We identified 350 decedents from coronary heart disease and 93 from stroke among 3,263 longshoremen in an 18-year follow-up after multiphasic screening examinations. Men with physically less active jobs, who expended 925 fewer calories per work day, sustained coronary death rates one-quarter higher than cargo handlers. Differences in coronary mortality were largest at younger ages and decreased steadily to disappearance at older ages.

Splitting the population into presumed high- and low-risk groups sorted out four other characteristics associated with coronary mortality: pre-existing heart disease, systolic blood pressure above mean levels, cigarette smoking of one or more

Figure 7—Relative death ratios for stroke among San Francisco longshoremen in an 18-year follow-up study, by paired combinations of three characteristics assessed in 1951.



P-YE in 1000's:	28.4	19.1	1.0	1.8	28.4	19.7	1.0	1.2	45.4	2.6	2.0	0.2
Observed no.	22	42	5	24	24	58	3	8	57	25	7	4
Expected no.	52.5	33.8	2.5	4.3	52.7	35.5	2.2	2.5	81.9	6.4	4.3	0.4

Age-adjusted death rates from stroke for longshoremen without either characteristic represent the baseline for comparison with rates for longshoremen with various combinations of the pair.

packs per day, and weight-for-height above mean levels. The risk of coronary mortality accompanying each of these characteristics was greater for individuals who were less active than for cargo handlers.

Longshoremen with more sedentary jobs sustained stroke death rates similar to those of cargo handlers in the 18-year follow-up. Three other characteristics, however, identified groups at high-risk of stroke mortality: pre-existing heart disease, systolic blood pressure above mean levels, and abnormal glucose metabolism.

The association between work activity and coronary mortality, when considered with the lack of such association with stroke mortality, suggests that physical activity influences the myocardium or its function more than the atherosclerotic process.

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